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Habitats of Alpine Plants in Jaljale Himal, Eastern Nepal, with Special Reference to *Rheum nobile* (Polygonaceae)

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Habitats for alpine plants at a sampling site located at an altitude of about 4200 m in Jaljale Himal, eastern Nepal, were classified into five types, each of which was characterized by its own plant community, and habitat conditions of slope exposure, inclination and substratum. Most of the alpine plants were restricted to a specific type or types of habitats, but *Rheum nobile* was not restricted and completed its life cycle in any habitat types.

Key words: alpine plant, habitat condition, Himalaya, *Rheum nobile*, vegetation

Introduction

There are several alpine plants in the Himalaya whose inflorescences are covered by semitransparent, pale cream-colored bracts. *Rheum nobile* Hook.f. & Thoms. is one of such plants which bears its flowers in a "greenhouse" consisting of its own bracts. We noted the habitat of this distinctive alpine plant in the Himalaya as part of our ecological and physiological studies carried out during a botanical research trek in Jaljale Himal, eastern Nepal, in the summer of 1991 (Ohba and Akiyama 1992, Terashima et al. 1993, 1995, Omori and Ohba 1996). Habitats vary from place to place even within the same area and responses of plants to such variation are expected to be different from species to species. We aimed to determine the habitat preferences of *Rheum nobiles* based on species-to-species differences in distribution patterns, which theoretically should be generated by responses to habitat variation within a sampling area.

Area studied and Methods

The study site was located at about 4200 m above sea level on a mountainside in Jaljale Himal, eastern Nepal (Fig. 1), where the alpine zone extends from about 4000 to 5000 m, from the upper limit of the *Rhododendron* scrub zone to the snow line (Kikuchi et al. in press). There are marked rainy and dry seasons in the area: 70–80% of annual precipitation is concentrated in the four months during the summer monsoon according to the report from Khumbu Himal (Inoue 1976). About 1500 mm of precipitation were recorded at temporary stations on peaks and ridges at high altitudes (5000–5500 m) on the southern side of the Himalaya in eastern Nepal during the monsoon period of 1976 (Yasunari and Inoue 1978). The daytime air temperature in summer is estimated to be 7°C to 9°C at 4200 m above sea

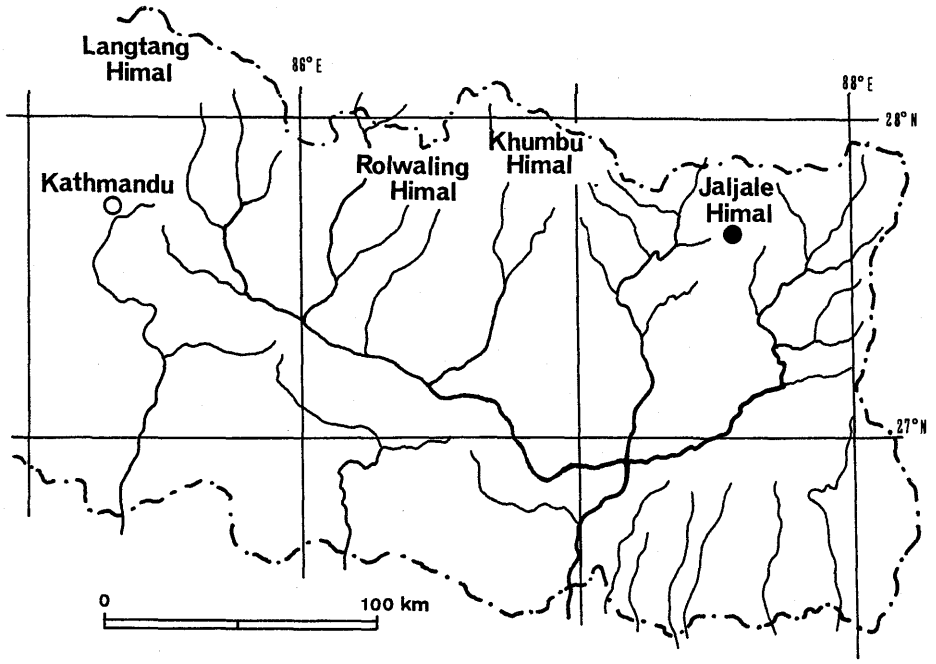

Fig. 1. Map of eastern Nepal showing the site investigated (solid circle).

level based on measurements by Kikuchi and Ohba (1988a) in Rolwaling Himal. Among eight types of plant communities described by Kikuchi et al. (in press) in Jaljale Himal, the *Kobresia nepalensis* community and the *Rhododendron anthopogon-Potentilla microphylla* community are widespread. The *Rhodiola coccinea* and the *Kobresia duthiei* communities were also sometimes found at the site. Relatively luxuriant communities, such as the *Potentilla contigua*, the *Bistorta vaccinifolia*, the *Primula stuartii* and the *Rhododendron anthopogon* communities were not found at the site.

We established sampling points every five meters along five vertical lines on north-, northeast-, southeast-, south- and southwest-facing slopes surrounding a lake. We established 1×1 m plots around individuals of *R. nobile* closest to each sampling point, or at the point itself if there were no plants of *R. nobile* within a 5×5 m square surrounding the point. We estimated the percent coverage for all species found within the plot, measured slope exposure and inclination at the center of the plot and recorded properties of the substrate. For plot and species classifications, we applied TWINSPAN and DECORANA. TWINSPAN is a divisive, hierarchical classification program which produces a coordinated classification of samples and species based on differential species (Hill 1979a). DECORANA is an ordination program which gives the positions of samples and species with respect to derived axes (Hill 1979b, Hill and Gauch 1980).

To determine the habitat of adult *Rheum nobile*, we measured slope exposure and inclination at the base of all accessible flowering individuals on the slopes on which we set the sampling lines.

Results

The eighty plots investigated were classified into 12 types as shown in the dendrogram (Fig. 2) of classification level 4 by TWIN-

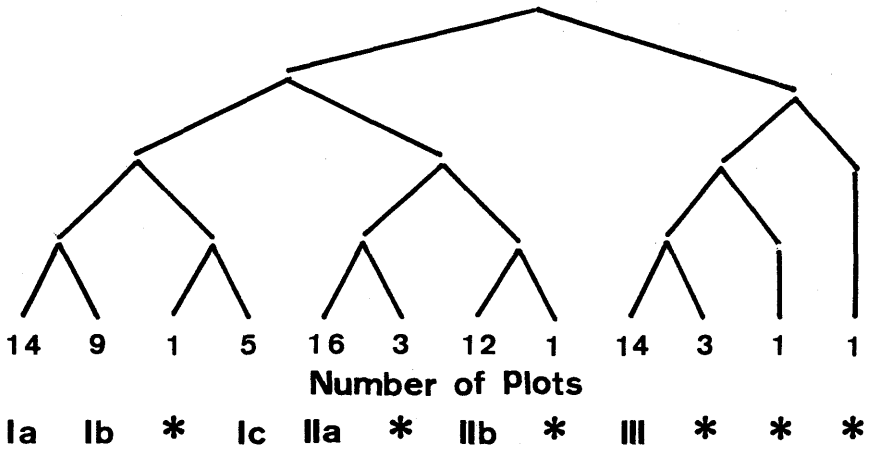

Fig. 2. Classification of plots based on TWINSPAN analysis of their plant communities.

SPAN analysis applied to the most frequent 28 species occurring eight times (10%) or more. However, only six of these classes, Plot Classes Ia, Ib, Ic, IIa, IIb and III, are considered in the present paper because the other six classes consisted of insufficient numbers of plots (three plots or less). Figure 3 shows DECORANA ordination diagrams for 70 plots comprising these six plot classes. They are plotted against the first and second ordination axes at the top and against the first and third axes at the bottom of the figure. The first axis reflects a difference in communities in Plot Classes Ia, Ib and Ic from the others, the second axis reflects differentiation among Plot Classes Ia, Ib and Ic, and the third axis reflects differences in Plot Class III from the others.

Figure 4 shows distributions of the plots against slope exposure and inclination measured at the center of the plots. Both Plot Classes Ia and Ib were found on slopes facing southeast, south and west but they tended to be different in slope inclination of their habitats. Plot Class Ia was found on slopes steeper than those of Ib. Plot Classes IIa and IIb were distributed on slopes facing west, north and east, and Plot Class Ic was on slopes facing northeast and east. Habitats of these three classes were similar in slope inclination. Plot class III was not affected by slope exposure nor inclination. Plot Classes Ia and Ib were usually found on exposed basement with very thin soil as shown in Table 1. On the other hand, Plot Class Ic was always over comparatively thick sediments. Both Plot Classes IIa and IIb were found on exposed basement or boulder sites. Plot Class III was almost always found on boulder-covered sites.

Thus, each plot class, except for Plot Classes IIa and IIb whose habitats could not be distinguished, was characterized by its own habitat conditions. Based on these findings, habitats of the investigated area were classified into five types. Each of these habitat types was characterized by slope condition, substratum and plot class on the basis of its plant community as summarized in Table 2.

The species examined were classified into seven classes by TWINSPAN at classification level 3 as shown in Table 3, where mean species cover for each plot class is also given. According to the results presented in this table and the habitat classification in Table 2, habitat use of species can be described as follows.

Species Class 1 tended to be found in habitats of Plot Classes Ia and Ib and characterized

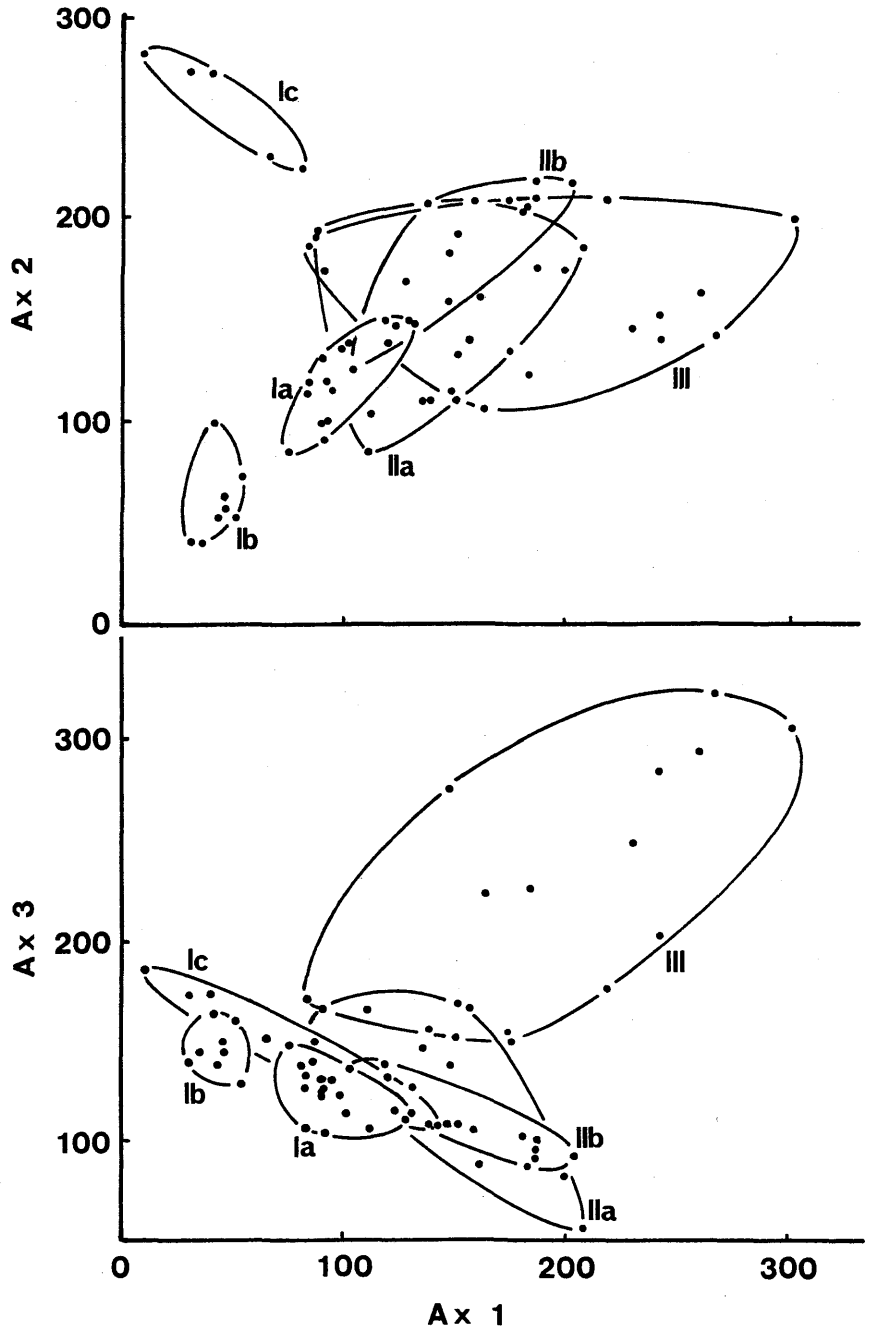

Fig. 3. DECORANA ordination diagrams for 70 plots comprising the six plot classes considered. The plots are plotted against first and second axes at the top, and first and third axes at the bottom.

Table 1. Number of plots differentiated by substratum

Plot Class	Substrata			Total
	Boulder	Basement	Sediment	
Ia	–	11	3	14
Ib	–	9	–	9
Ic	–	–	5	5
IIa	6	10	–	16
IIb	7	5	–	12
III	11	3	–	14
Total	24	38	8	70

Table 2. Summarized characteristics of habitat types

Habitat Type	Exposure	Inclination	Substratum	Plot Class
1	E, S, W	Steeper	Basement	Ia
2	E, S, W	Gentler	Basement	Ib
3	N, E	All	Sediment	Ic
4	W, N, E	All	Basement Boulder	IIa, IIb
5	All	All	Boulder	III

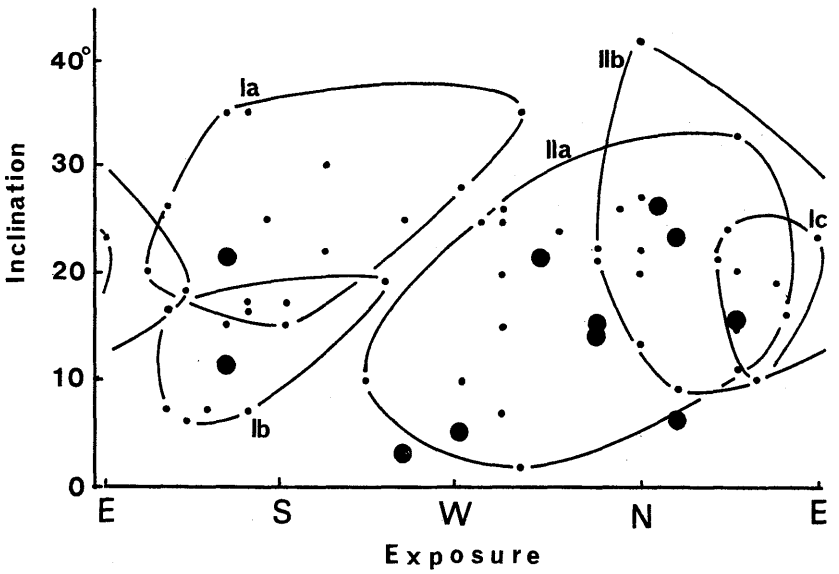

Fig. 4. Slopes conditions as to exposure and inclination of the plots classified. The larger circles show the plots of Plot Class III.

by exposed basement facing east, south and west. Species Class 2 preferred steeper habitats of Plot Class Ia to the gentler one of Plot Class Ib among such habitats. Species Class 3 inhabited various habitats, except the boulder sites of Plot Class III. Species Class 4 was also widely found but it tended to avoid Plot Classes Ia, IIb and III, characterized by boulders and comparatively steep basement. Very common species found in all habitats were those of Species Class 5, in which *R. nobile* was included. Species Classes 6 and 7 tended to be associated with habitats of exposed basement and boulder sites facing west, north and east in Plot Classes IIa and IIb, and the boulders themselves of Plot Class III. Particularly, Species Class 7 tended to be associated with boulders in Plot Class III.

Figure 5 shows habitats of mature individuals of *R. nobile* with flowers. They were plotted against slope exposure and inclination measured at the point where each individual grew. There were no special slope conditions in the habitats of flowering *R. nobile.*

Discussion

Each of the three axes of the DECORANA ordination reflected a difference in communities (Fig. 3), so that there should be at least three factors affecting the community defferentiations, although Plot Classes IIa and IIb were not divisible on any axes. Those factors are most probably equivalent to habitat characteristics of slope exposure, slope inclination and substratum. Based on these habitat characteristics, is described the five habitat types shown in Table 2. According to our observations, boulder sites of Habitat Type 4 were rich in matrix among boulders and this matrix was assumed to support plants. On the other hand, plants inhabited boulders on themselves or the thin organic substance covering them in Habitat Type 5. Plot Class III in Habitat Type 5 was assumed to be strongly

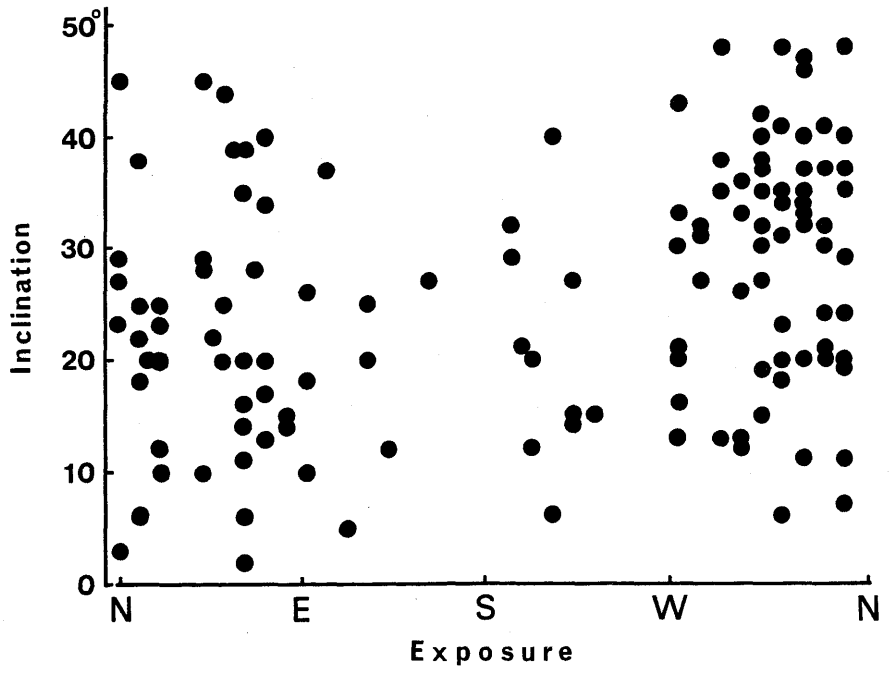

Fig. 5. Slope conditions as to exposure and inclination of flowering *Rheum nobile.*

Table 3. Classification of species by TWINSPAN at level 3 and mean species cover (%) for plot class. '+': lower than 0.1% in cover

Species	Species Class	Plot Class Ia	Ib	Ic	IIa	IIb	III
Pedicularis sp.		1.6	1.1		1.0		+
Potentilla coriandrifolia	1	1.5	32.2	+	+		+
Parnassia nubicola		1.2	+	+			+
Anemone demissa		2.6	+	1.6	+	+	
Cremanthodium pinnatifidum		4.1	1.9	1.0	1.2		+
Saussurea sughoo	2	1.4	+				
Lignariella sp.		+				+	+
Primula primulina		+					
Kobresia nepalensis		56.4	33.3	28.0	21.3	30.0	2.3
Umbelliferae	3	+	+	+	+	+	+
Swertia multicaulis		1.1	1.6	1.8	6.0	3.3	+
Rhododendron anthopogon			2.2	54.0	3.2	1.3	1.3
Kobresia duthiei	4	3.5	5.2	1.0	2.1	+	+
Bistorta jaljalensis		+	+	1.0	1.6	+	+
Rhododendron setosum			4.6		+		+
Potentilla microphylla		5.4	6.9	0.8	9.1	4.1	3.3
Rheum nobile	5	7.3	4.4	11.0	5.6	35.9	2.9
Kobresia sp.		+	+	+	+		
Parnassia pusilla					1.0	1.3	+
Arenaria sp.					+	+	+
Saxifraga congesta	6	+		+	2.0	+	+
Poa eleanorae		+			+		+
Juncus leucanthus		+	+	+	+	+	1.1
Sibbaldia sp.					+	+	+
Paroxygraphis sp.		+	+		+		+
Rhodiola coccinea	7			+	+	+	2.6
Koenigia delicatula		+			+		+
Umbelliferae						+	+

associated with this extreme edaphic condition. This is probably one of the reasons why Plot Class III was independent of slope exposure (Fig. 4).

The difference between slopes facing north and those facing south concerns the basic distribution pattern of vegetation in the Himalayan alpine zone (Kikuchi and Ohba 1988b, Kikuchi et al. in press). In this study, there was an apparent difference in distribution between Plot Classes Ia and Ib on slopes facing south and Plot Classes Ic, IIa and IIb on slopes facing north (Fig. 4). Furthermore, the former two were differentiated according to slope inclination (Fig. 4) and the latter according to substrata (Table 1). Plot Class III was associated with an extreme edaphic condition of boulders. These differences in vegetation

are based on differences in species compositions of plant communities, or differences in habitat preferences of their component species. Each species has a narrow or wide habitat preference of its own. As mentioned above, *R. nobile* was distributed throughout the habitats as were other members of Species Class 5 (Table 3). This lack of avoidance of particular habitats is a distinguishing characteristic of *R. nobile* while other species have more or less certain habitat preferences.

Rheum nobile had very high coverage in Plot Class IIb in the habitat facing north, indicating that it prefers such habitats. However, Figure 5 shows that it can complete its life cycle in any habitat, not only those facing north but also those facing south.

Rheum nobile is a monocarpic plant which flowers once after a number of years of growth, then dies. Consequently, a population of *R. nobile* consists of great number of seedlings and young plants and a small number of adults. Our observations along the line might have actually been carried out on immature individuals which are in the majority. This is the reason why we examined flowering *R. nobile* in various habitats. Unfortunately, habitats facing south were not as numerous in this observation because there were no wide slopes facing south in the area investigated. However, observation of flowering *R. nobile* in habitats facing south in Figure 5 sufficiently shows that this species can complete its life cycle in such habitats as well as in those facing north.

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菊池多賀夫[a]，M. N. スベジ[b]，大森雄治[c]，大場秀章[d]：**東部ネパールジャルジャレ・ヒマールにおける高山植物の立地条件，特にセイタカダイオウについて**

ネパール東部のヒマラヤ（ジャルジャレ・ヒマール地域）標高約4200mの高山帯で，*Rheum nobile*を中心に，植物種の立地条件を調べた．*Rheum nobile*は苞が半透明となって花序を包む，いわゆる「温室」植物の1種である．方位の異なる複数の斜面に設定した測線にそって方形区法による植生調査を

行い，得られた群落組成の分析から6群落タイプを区分した．それぞれの立地斜面方位，傾斜および基質から分析した結果，東-南-西向きで基盤が露出している急斜面，東-南-西向きで基盤が露出している緩斜面，北-東向きで表層に風化物質を載せる斜面（傾斜は任意），礫原（傾斜は任意），礫原（方位・傾斜は任意）の5タイプを互いに異質な植物群落を成立させる立地として区分した．種のレベルでも，多くの種はこれらの立地タイプのどれか，または幾つかに限って出現した．*Rheum nobile* も北向き斜面に成立する植物群落に被度高く出現する傾向はあるものの各タイプの立地にわたってみられ，特に開花個体は各方位，傾斜にわたって万遍なく存在した．

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